THE LOMBARD OVERTHRUST AND RELATED GEOLOGICAL FEATURES

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TOPOGRAPHIC AND STRUCTURAL FEATURES

The region involved in this discussion lies near the head of the Missouri River in Montana. The chief topographic features are hilly dependencies of the Little Belt Mountains.

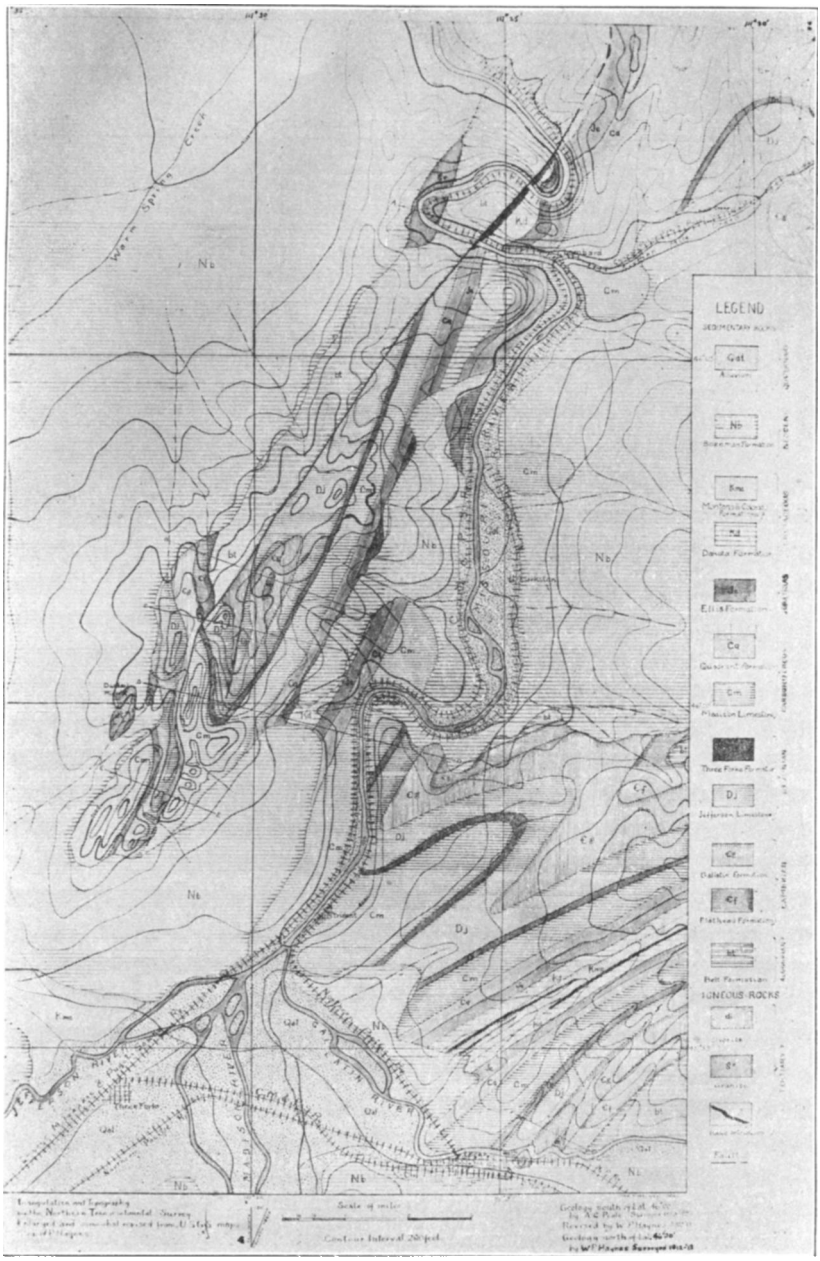

FIG. 1.—Geological map of the region about Three Forks, Montana

The principal structural features are shown on the map (Fig. 1) and in the structure sections (Fig. 2). The dynamic features consist of folds and faults.

FOLDS

There is no indication that any marked deformation took place in this region during the Paleozoic and Mesozoic eras. At the close of the Cretaceous period, probably, the great series of sediments which had been accumulating began to be deformed. In this region they were compressed into a series of closed folds with a general northeast-southwest trend. These folds are usually overturned to the southeast and pitch to the southwest. Two of these folds were named by Dr. Peale[1] the Horsehoe anticline and the Cottonwood isocline, both situated north of Logan, Montana.

East of Lombard, in the vicinity of Crane Station, there is a northward-pitching anticline. In the long ridge west of the Missouri River there is an elongate domal structure (Fig. 3) the western side of which is interrupted by a normal fault and obscured by an extensive overthrust. The southern part of this elongate dome is overturned to the east and pitches steeply to the south (Fig. 1; Fig. 2, section D-D; and Fig. 4).

FAULTS

The Lombard overthrust.—The most important feature of the structural geology of the region is an extensive overthrust fault which has its southern end in the ridge north of Three Forks, and extends a distance of at least 13 miles along the ridge to the northern border of the map. The writer proposes the name "Lombard overthrust" for this feature, because it is well exposed in the canyon of the Missouri River near Lombard. Here the fault plane dips about 40° to the west. This fault has brought strata of the Belt Series over strata of Cretaceous age in the north, near Lombard, and has brought the upper member of the Cambrian into contact with the Carboniferous Madison limestone in the southern end of the ridge (Figs. 2 and 5). The maximum displacement on the fault plane near Lombard cannot be very closely estimated,

[1] A. C. Peale, *Bull. U.S. Geol. Survey, No. 110*, 1893.

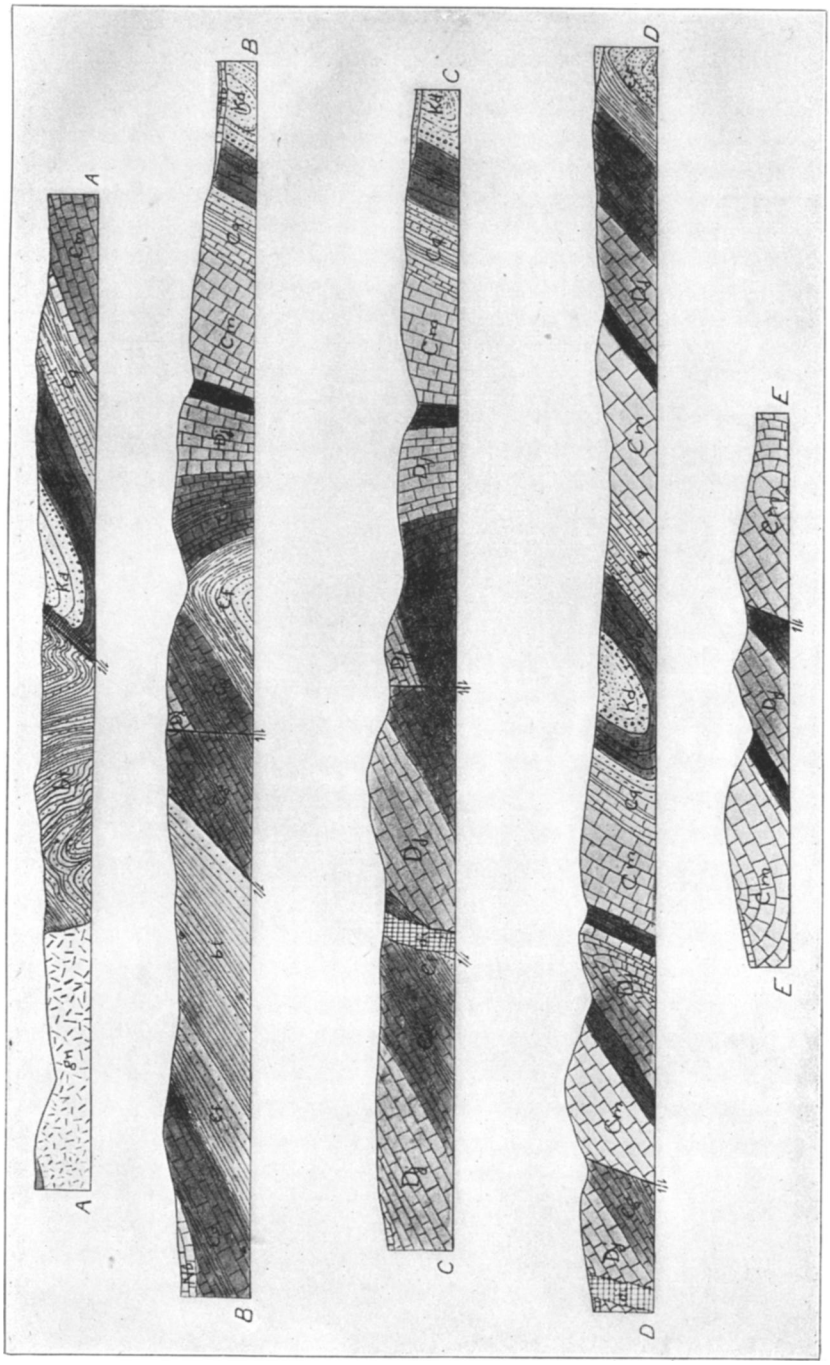

FIG. 2.—Geological sections

but it is approximately two miles, and strata which are stratigraphically about 6,800 feet apart are here in contact.

The age of the Lombard overthrust cannot be definitely determined, but it is certainly younger than the Cretaceous strata exposed near Lombard, and probably older than the Lower Oligocene deposits which occur near the southern end of the ridge and are apparently undisturbed. It may therefore be assigned with some uncertainty to very late Cretaceous or early Tertiary time.

A normal fault.—The only normal fault observed in this region appears in the highest part of the ridge north of Three Forks and west of the Missouri River. This fault cuts across the western limb of the elongate dome already noted, and has caused a repetition of the upper part of the Gallatin formation and the base of the Jefferson limestone (see Fig. 2, section C-C). This fault has a length of about two miles and a diminishing throw to the south. It could not be traced to its intersection with the overthrust fault, but the displacement apparently dies out in that direction also.

The age of the normal faulting is considered to be the same as that seen farther south in the Three Forks quadrangle, which is dated as probably Pliocene.

STRATIGRAPHIC GEOLOGY

PRE-CAMBRIAN

The oldest rocks exposed in this region are a series of somewhat altered sediments which occur below the base of the Cambrian, and are considered to be part of the Belt Series, which are typically exposed in the Little Belt Mountain region to the north and northeast. The exposures of the Belt formation occur along the Gallatin River east and northeast of Logan, and also north of Three Forks, in a widening strip which trends northeastward and crosses the Missouri River at the double horseshoe bend west of Lombard (Fig. 1).

The exposures north of the Gallatin River are of rather coarse micaceous sandstones and shales with thinly bedded siliceous limestones. They are not divisible on the basis of lithological characters into the various formations which characterize the Belt Series at the type localities.

The extensive exposure of the Belt Series north of Three Forks, which, so far as the writer was able to ascertain, has not been described before, consists of two fairly distinct formations which are considered to be equivalent to the Spokane and Empire formations of the Belt Series.

Spokane formation.—In the vicinity of the double horseshoe bend of the Missouri River there is a fine section through the

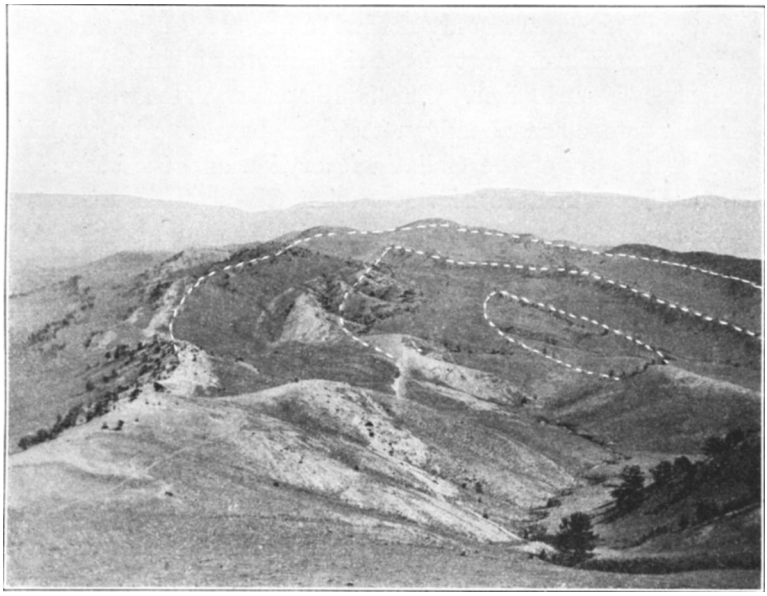

FIG. 3.—Domal structure in ridge west of the Missouri River

Spokane formation. The formation at this place consists of a thick series of well-stratified red and green slates with frequent layers of ripple-marked and mud-cracked sandstone. The finer beds are mostly very hard and siliceous and may be called argillites or even metargillites. At several places in the section distinct folds are visible, and also some faults. The minimum thickness of the formation in this section is 1,650 feet, but the average thickness is probably considerably greater than these figures.

Empire shale.—This formation, which overlies the Spokane formation, is exposed in a long strip west of the Missouri River,

extending from near the southern border of the Fort Logan Quadrangle near latitude 46° to the double horseshoe bend. It consists of evenly bedded, pale greenish shales with a few bands of quartzite. The quartzite occurs in beds from 1 to 25 feet thick. The formation is in apparent conformity with the overlying Cambrian

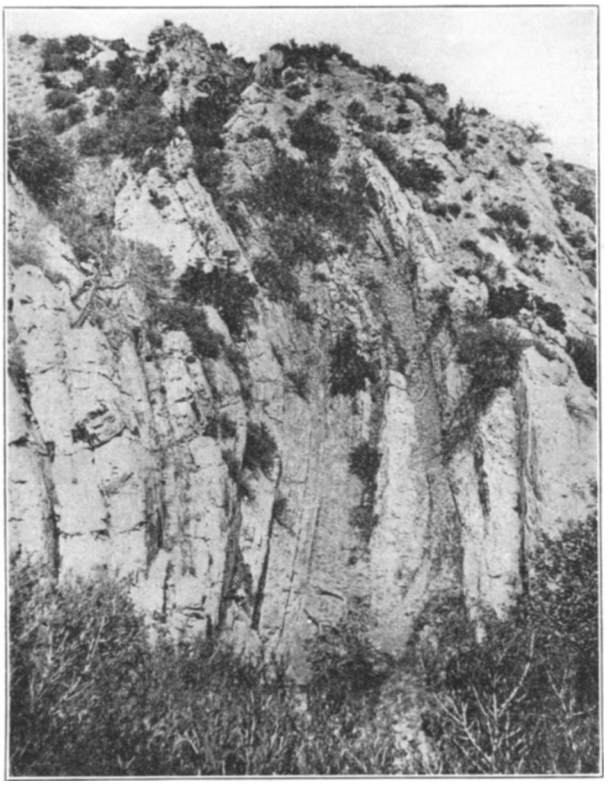

FIG. 4.—Folded Madison limestone near southern end of ridge, north of Three Forks.

quartzite near the southern end of the exposure, but inasmuch as the contact was traced for only a short distance an unconformity with very slight angular discordance may have been overlooked. Although the complete section of the Empire shale was not seen, it is probable that 800 feet is a conservative estimate for the thickness of the formation in this area.

There is still much disagreement among the various geologists who have worked in the parts of the Cordillera where the Belt Series is exposed, in regard to the age of the series and the correlation of the different formations in it. The writer is disposed to agree with the correlation in a recent report on the Philipsburg quadrangle in Montana,[1] in which strong evidence is shown for a rather long erosion period between the Belt Series and the overlying Cambrian quartzite. The two formations identified by the writer as the Empire and Spokane formations are therefore considered to be of Pre-Cambrian, Algonkian, or Proterozoic age.

PALEOZOIC

The Paleozoic formations recognized by the writer in this region are for the most part continuous with those described by Dr. Peale in his report on the "Paleozoic Section in the Vicinity of Three Forks, Montana,"[2] and later in the Three Forks Atlas Folio.[3] His descriptions of the formations are very good and apply equally well to the exposures in the region to the north, on the Fort Logan Sheet. There are some additional facts concerning the thicknesses and ages of the formations and a few changes in the nomenclature which will be discussed under the following headings:

Cambrian.—A comparison of sections made by different geologists in the neighboring quadrangles shows that the seven lithologic divisions noted by Dr. Peale in the Three Forks quadrangle are persistent throughout southwestern Montana and the neighboring part of Wyoming. It seems advisable to have but one name for each of these divisions, and since locality names are preferable to descriptive names the writer suggests that the nomenclature used by Dr. Weed[4] in the Little Belt Mountains Folio be adopted for the Cambrian throughout the whole region where these seven lithologic divisions are recognized.

For purposes of mapping it seems best to keep the broader divisions used by Dr. Peale, the two lower members forming the Flathead formation and the upper five the Gallatin formation.

[1] *Prof. Paper 78. U.S. Geol. Survey.* [2] *Bull. U.S. Geol. Survey, No. 110.*

[3] Atlas Folio, *U. S. Geol. Survey, No. 24.*

[4] Atlas Folio, *ibid., No. 56.*

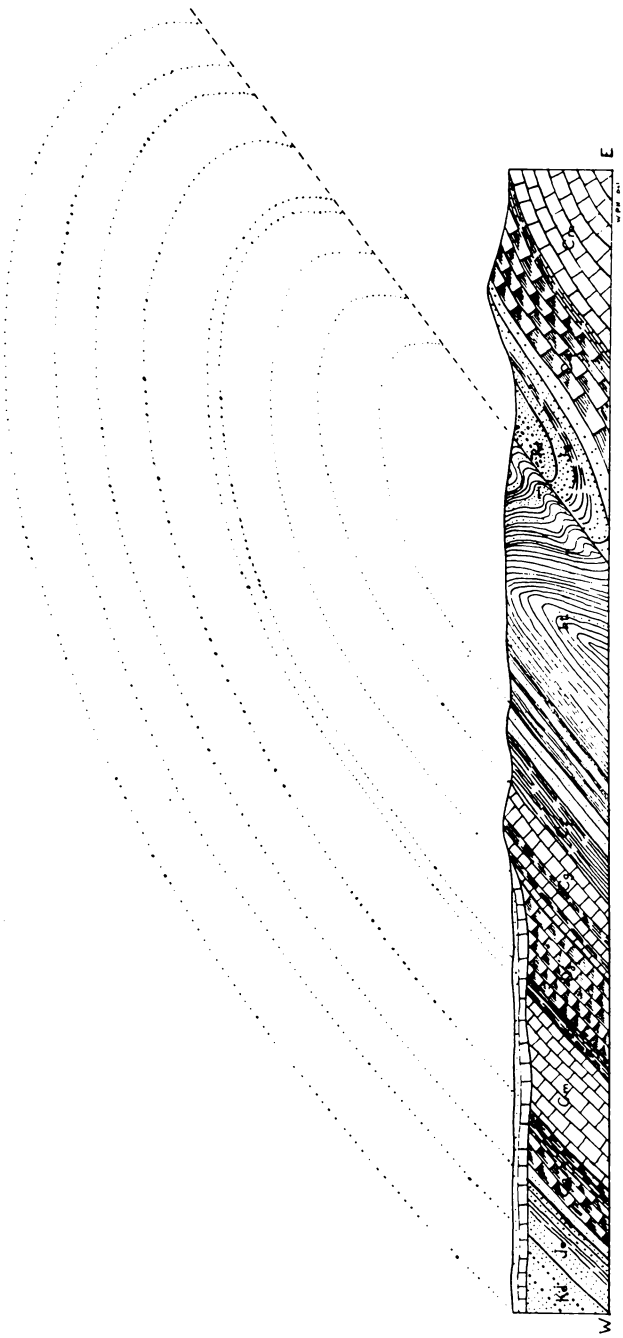

FIG. 5.—Diagrammatic section of the Lombard overthrust

The following section of the Cambrian northeast of Logan, Montana, was measured by the writer.

Dr. Peale's Nomenclature		Dr. Weed's Nomenclature	Thickness
1. Pebbly limestone	=	Yogo limestone	75 feet
2. Dry Creek shale	=	Dry Creek shale	20
3. Mottled limestone	=	Pilgrim limestone	300
4. Obolella shale	=	Park shale	280
5. Trilobite limestone	=	Meagher limestone	175
6. Flathead shale	=	Wolsey shale	450±
7. Flathead quartzite	=	Flathead quartzite	200
		Total	1,500± feet

Fossils from the Yogo limestone have been submitted by the writer to Dr. Walcott, who considers them of Upper Cambrian age, while those from the Meagher limestone are regarded by him as of Middle Cambrian age. Apparently Lower Cambrian strata are entirely absent in sections in this region. Although the boundary between the Middle and Upper Cambrian strata has not been definitely ascertained, it is likely that it comes between members 2 and 3.

Absence of Ordovician and Silurian strata.—In all of the sections studied by the writer in the Three Forks quadrangle and the neighboring district to the north, the Jefferson limestone lies in apparent conformity on the Yogo limestone without any intervening formations. The lower portion of the Jefferson limestone has been considered by Dr. Peale and others as probably of Ordovician and Silurian ages, although no fossils of those periods have been found in it. Dr. Kindle[1] has described the Jefferson limestone and its fauna and established its age as chiefly Middle Devonian with the lower part probably Lower Devonian.

In one or two good sections studied by the writer some rather poorly preserved corals were found within 25 feet of the base of the formation. These were identified as *Favosites* cf. *limitaris* Rom., which is rather common in much of the Jefferson limestone. The presence of these fossil corals is regarded as indicating the Devonian age of all of the Jefferson limestone, and since the gray Yogo lime-

[1] E. M. Kindle, *Bull. Amer. Pal. No. 20*, 1908.

stone immediately below the brown Jefferson dolomitic limestone contains Upper Cambrian fossils, the writer believes that at this contact there is a disconformity involving a hiatus in the sedimentary record of this region from the close of the Upper Cambrian to Lower Devonian time.

Further evidence in favor of this disconformity and stratigraphic overlap is brought out by the presence in sections in neigh-

FIG. 6.—Cliff of Jefferson limestone north of Crane Station

boring regions to the west and southwest of intervening strata of different lithologic character between the Yogo limestone and the Jefferson limestone, which in some cases contain fossils of Ordovician and Silurian ages. One very complete section from the Randolph quadrangle[1] in northeastern Utah, with 3,000 feet of Ordovician and Silurian strata between the Upper Cambrian limestone and the Jefferson limestone, shows very clearly the hiatus in the sections in the Three Forks quadrangle and the neighboring region to the north and northeast.

[1] G. B. Richardson, *Amer. Jour. Sci.*, XXXVI (1913), 406–416.

Devonian.—The strata of Devonian age in this region are divided into two distinct formations, the Jefferson limestone and the Three Forks formation.

Jefferson limestone: The Jefferson limestone is well described by Dr. Peale[1] as a massively bedded brown to dark-gray or black crystalline magnesian limestone with the composition of a dolomite. It is well exposed in the region under discussion in the form of brown cliffs 100 to 200 feet high (Fig. 6). In a few of the ridges

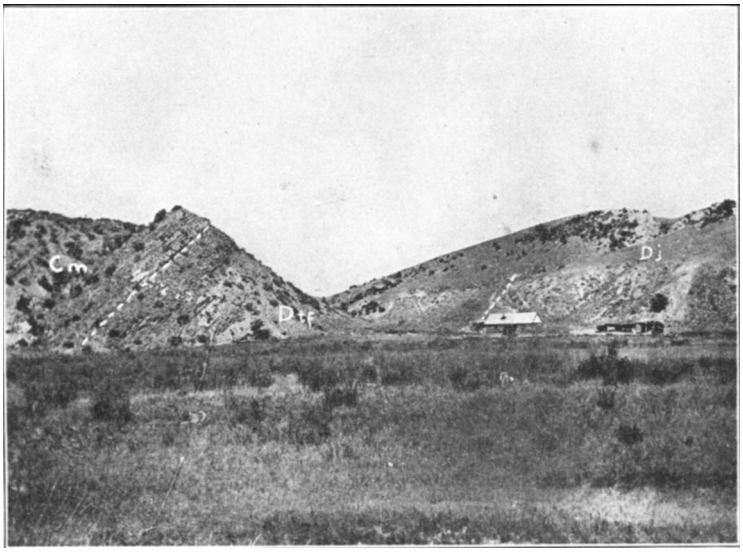

FIG. 7.—Valley in Three Forks formation, near Rekap Station

north of Three Forks the limestone is black in color, but shades of brown are the customary colors. In this region the Jefferson limestone has a thickness of about 500 feet, but it diminishes in thickness to the north and northeast, as noted in the sections in adjacent quadrangles.

Three Forks formation: Lying upon the Jefferson limestone is a series of shales and limestones which have been described by Dr. Peale[2] and named the Three Forks shales. The writer has made a careful study of this formation in all of this region, and has measured numerous sections and made extensive collections of

[1] A. C. Peale, *Bull. U.S. Geol. Survey, No. 110*, 1893, pp. 27–28.

[2] *Ibid.*, pp. 29–30.

fossils from certain of the members. A detailed account of the formation and a description of some of the fauna is in process of publication elsewhere,[1] so that only the more important points will be mentioned here.

In all of the region included in Fig. 1 the Three Forks formation shows seven fairly distinct lithologic divisions. These members are well shown in the following section of the formation made northeast of Logan near the Gallatin River.

Base of Gray Madison Limestone

1.	Yellow arenaceous limestone	30 feet
2.	Pale-yellow arenaceous shale	30
3.	Purple fissile shale	0.5
4.	Dark bluish-gray nodular limestone	9.5
5.	Fissile green shale	47
6.	Yellow crystalline limestone	15
	Gray limestone	12
7.	Yellow and orange shales	78
	Top of the Jefferson limestone. Total	222 feet

Another section farther north along the Missouri River at Rekap Station (Fig. 7), shows the variation in thickness of the different members.

1 and 2.	Yellow sandy limestone and shale	74 feet
3.	Black coaly shale	6
4.	Nodular gray limestone	7
5.	Fissile green shale and Gray and yellow limestone	120
7.	Pebbly yellow and reddish limestones and shales	80
	Total	287 feet

It will be noted from these two sections that the members consist of limestones as well as shales, so that the term "Three Forks formation" is preferable to Dr. Peale's name "Three Forks shales."

In the region north of Three Forks and west of the Missouri River there are numerous good exposures of the Three Forks

[1] *Annals Carnegie Museum*, Pittsburgh.

formation, whose erosion has formed some rather prominent valleys, as shown on the map and in Figs. 7, 8, and 9. These valleys extend in a general north-south direction and are nearly parallel with one another. This repetition of the formation is due partly to folding and partly to faulting.

The easternmost valley eroded in the Three Forks formation is very narrow and shallow and extends northward along the eastern

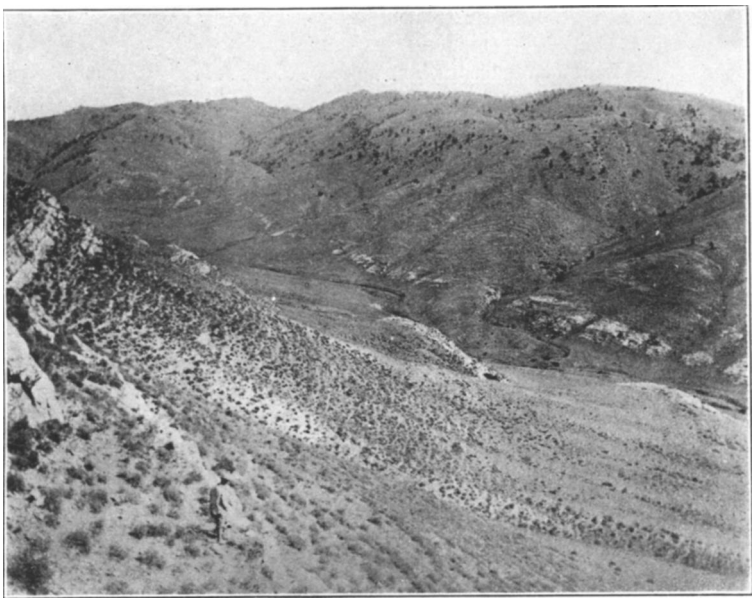

FIG. 8.—Great valley in Three Forks formation. Ridge north of Three Forks

slope of the range of hills for five or six miles. The exposures are poor because the strata are vertical or overturned and much crushed by close folding.

This valley, at its southern end, swings around to the west and opens into a much larger valley, which extends to the north for about two miles. The structure which is the cause of this curious arrangement of the valley is that of a southward-pitching anticlinal fold which is overturned to the east. The strata in this very large valley are in the western limb of the anticline (Figs. 8 and 9).

West of the overthrust fault there is another valley formed in the Three Forks formation. Numerous good sections of the formation were obtained in the small tributary gullies which cut across the dip of the strata on the western sides of these valleys.

The fossiliferous members of the formation are Nos. 1, 2, 4, and 5. The general conclusions from a study of the fauna are that the formation is very late Devonian in age, as reported by Dr.

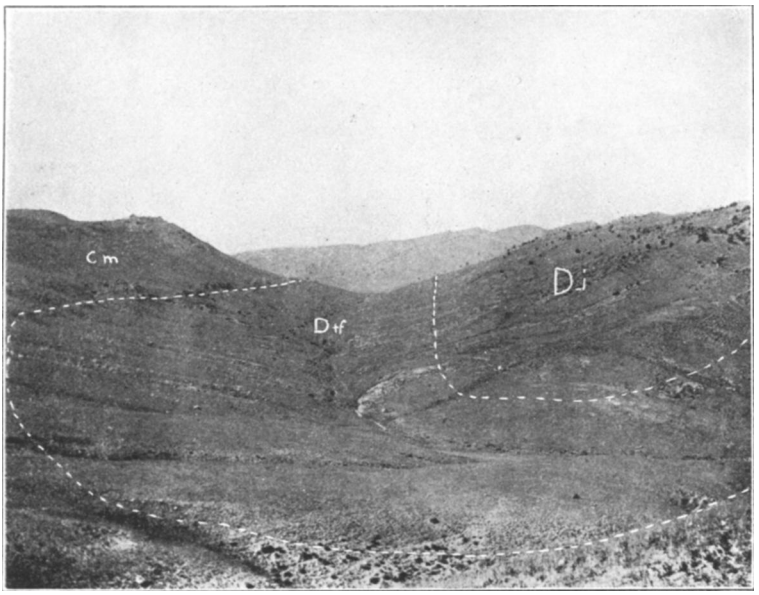

FIG. 9.—View north from southern end of valley, at apex of southward pitching anticline.

Raymond in 1907,[1] and probably represents a transition into the Mississippian in its upper part in members 1 and 2.

Carboniferous.—Throughout the mountainous part of southwestern Montana the Carboniferous formations are very prominent and form conspicuous and precipitous cliffs. In the region about Three Forks the Carboniferous strata attain a thickness of from 1,500 to 2,000 feet.

[1] P. E. Raymond, *Amer. Jour. Sci.*, XXIII (1907).

Madison limestone: The lower formation has been named by Dr. Peale[1] the Madison formation and was subdivided by him into three members; (1) the Laminated limestones at the base; (2) Massive limestone in the middle, and (3) Jaspery limestone at the top. The thickness of the Madison formation near Logan is about 1,300 feet. Although it forms conspicuous gray cliffs along the ridge west of the Missouri River, its best exposures are seen where

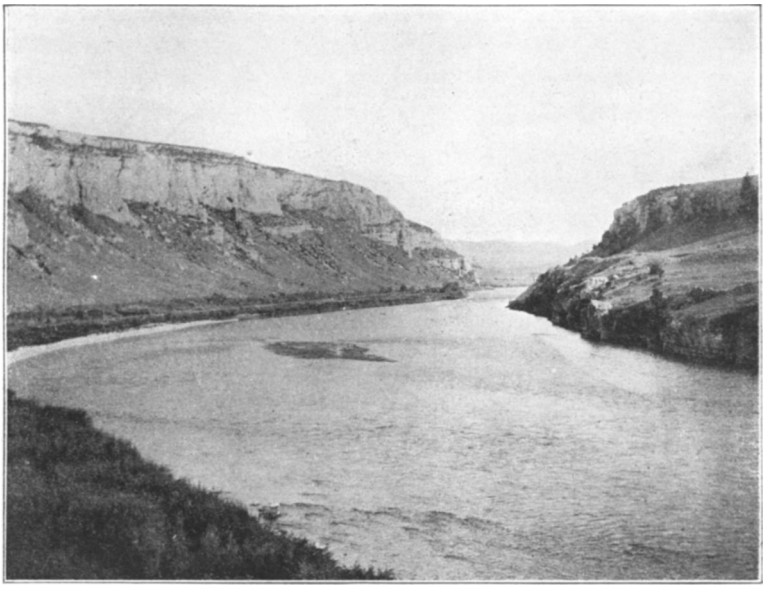

FIG. 10.—Missouri River in canyon in Madison limestone

the river has cut a deep canyon through it near Lombard, and also in the smaller canyon along Sixteenmile Creek, east of Lombard (Figs. 10 and 11).

A large collection of fossils was made by the writer from the Madison formation in all parts of the region. These fossils all pointed to the general Lower Mississippian age of the Madison limestone.

Quadrant formation: Lying in apparent conformity upon the Madison limestone in this region is the Quadrant formation which

[1] A. C. Peale, *op. cit.*, p. 33.

forms the upper part of the Carboniferous system. The Quadrant formation consists of two members, as noted by Dr. Peale.[1] The lower is a red arenaceous limestone overlain by bands of shale and limestone. The upper member is thinly bedded cherty limestones alternating with quartzite layers. The top of the formation is somewhat arbitrarily placed by Dr. Peale at the base of a very massive and persistent quartzite layer which is

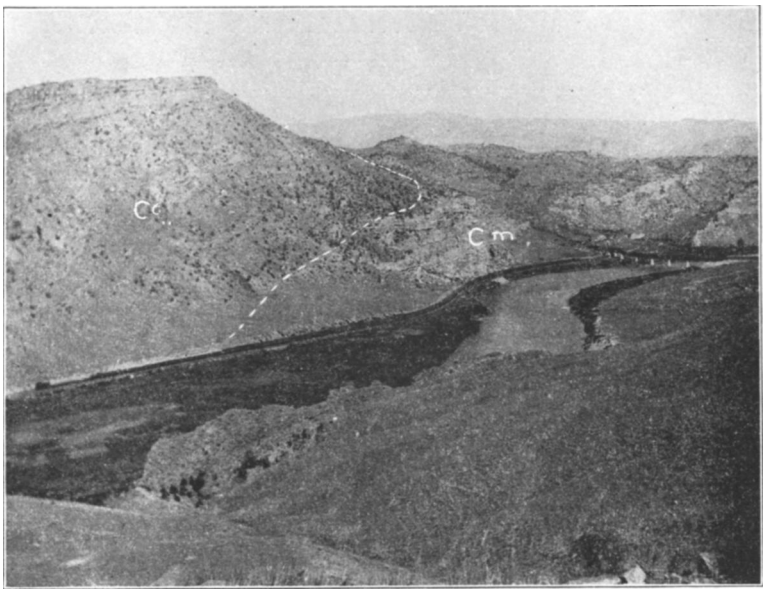

FIG. 11.—Double horseshoe canyon of the Missouri River. View east showing Lombard Station, and mouth of Sixteenmile Creek canyon.

considered to be the basal member of the overlying Ellis formation of Mesozoic age.

The writer obtained a thickness of about 400 feet for the Quadrant north of Logan and 674 feet near Lombard. The exposure of the Quadrant formation in the canyon near Lombard is excellent, and a section was measured straight up the side of the canyon from the top of the massive cliff of the gray Madison limestone to the

[1] A. C. Peale, *op. cit.*, p. 39.

top of the massive quartzite layer which forms the rim of the canyon. The strata here strike N. 40° E. and dip 30° west (Fig. 11).

Massive pink and yellow quartzite (base of Ellis formation?)	16 feet
Quartzite and arenaceous limestone in alternating layers	60
Massive white quartzite, limonite stains	9
Limestone breccia	2
Brown arenaceous limestone	62
Grayish-brown arenaceous limestone and talus	62
Pink arenaceous limestone in cliff	36
Yellowish-red arenaceous limestone	47
Gray limestone in cliffs, shaly at base	10
Reddish shale	30
Greenish shale	57
Buff shaly limestone and talus	100
Gray bituminous limestone in cliff, with black shale layers	45
Compact gray and yellowish-brown limestone	24
Black coaly shale with calcareous bands and gypsum veins	20
Brown crystalline limestone	4
Coaly black shale, very fossiliferous	50
Yellow arenaceous limestone in cliff, some quartzite bands	46
Red shaly limestone	10
Total	674 feet

The fossils collected from the Quadrant formation indicate that it is probably of Lower Pennsylvanian (Pottsville) age. The absence of any strata referable to the Tennesseic suggests the presence of a disconformity between the Madison and Quadrant formations, although no other evidence of such a hiatus was observed by the writer.

MESOZOIC

Mesozoic formations are rather poorly exposed in this region and were not studied in detail by the writer. They consist of shaly limestones and sandstones which are generally much less resistant than the Paleozoic limestones and therefore usually occupy lowland areas. These Mesozoic strata border the Missouri Valley on both sides, and the more resistant layers form low ridges which are parallel with the trend of the higher Paleozoic hills.

In this region the Ellis formation, consisting of sandy shales and limestones with numerous layers filled with pelecypod shells, lies on the Quadrant formation with no observed discordance of dip. In the region to the south there is a well-marked reddish sandstone formation of probable Triassic age intervening between the fossiliferous Ellis and the Quadrant. Since the Ellis fossils are considered to be Jurassic in age, it seems clear that there is a disconformity in this part of the sections of this region.

Above the Ellis formation is a series of sandstones and conglomerates which have been called the Dakota sandstone by Dr. Peale, but they have recently been shown to be more probably the equivalent of the Kootenai formation of the region to the north.[1] These sandstones are therefore of probable Lower Cretaceous age. Strata of Montana and Colorado age were identified by Dr. Peale in the hills north of Logan, but there is now some doubt as to whether they can be referred to a horizon as high as that.

TERTIARY

All of the Mesozoic and Paleozoic strata were involved in the extensive orogenic movements which began at the close of the Cretaceous in this region.

The type of folding and the associated overthrust faulting has already been described in this paper. Extensive erosion reduced the region to comparatively low relief in Tertiary times. The great lowland areas were filled in by sedimentary deposits of sandstone, limestone, and volcanic ash to a great depth. The major features of the present drainage were established on this late Tertiary surface and gradually, through uplift and erosion, they were brought into discordance with the underlying structure, as is well shown by the double horseshoe canyon of the Missouri River west of Lombard.

This whole series of Tertiary valley sediments has been grouped under the heading of the Bozeman formation for convenience in mapping. Dr. Peale's name "Bozeman Lake Beds" seems no

[1] W. R. Calvert, *Bull. U.S. Geol. Survey. No. 471–E*, 1912, p. 53.

longer applicable, since they have been shown to be due to subaerial and fluviatile deposition rather than to lakes.[1]

The Bozeman formation here is chiefly of Miocene age, but in some parts of the region strata of Oligocene (White River) age have been identified.

PLEISTOCENE

The hills in this region were evidently too low for local glaciation and no signs of regional glaciation have been observed as far south as this in Montana. Gravel terraces along the rivers indicate greatly increased stream action in Pleistocene times.

IGNEOUS ROCKS

The igneous rocks in the region north of Three Forks are relatively unimportant, and are in the form of rather small intrusions of three different rock types.

GRANITE

About two miles west of Lombard, in the double horseshoe bend, the Missouri River flows for a short distance through a gorge cut in an intrusive mass of granite. Only the eastern boundary of this granite could be accurately mapped, but the approximate western limits are noted on the map.

The granite is of a light-gray color, with a medium fine texture and a somewhat porphyritic structure. The minerals recognized in a megascopic examination are white and grayish feldspar somewhat kaolinized, quartz in small amounts, and hornblendes mostly altered to chlorite. Under the microscope the feldspars are seen to be deeply kaolinized, but are chiefly orthoclase with some albite. There is a considerable amount of hornblende which is altered in part to chlorite and epidote. Some biotite and magnetite are also present.

In places this rock is almost entirely without quartz and therefore grades into a syenite. It seems to correspond closely with the description of the syenite of Yogo Peak[2] and vicinity in the Little Belt Mountains, which is noted as grading into a granite-syenite-

[1] H. F. Osborne, *Bull. U.S. Geol. Survey, No. 361*, 1909, p. 28.

[2] Atlas Folio, *U.S. Geol. Survey No. 56*, 1899.

porphyry. The granite has a well-developed set of joints which strike northeast and dip 80° east, and are about parallel with the contact with the Belt Series.

The age of the granite cannot be definitely determined at this place, but it is probably about the same age as the granitic and syenitic intrusions of the Little Belt Mountains, which are post-Cretaceous and probably early Tertiary in age.

DIORITE

Small irregular intrusive masses of diorite and diorite porphyry occur in the vicinity of Dunbar's mine, north of Three Forks. These intrusions cut the white Tertiary limestones which at this locality are considered to be of Lower Oligocene age. The diorite was observed to have nearly vertical contacts with the limestone and to occupy a much smaller area than is indicated on the geologic map of the quadrangle. The diorite porphyry seems to be a local variation in the normal diorite and its distribution can be shown only on a detailed map of the district.

Specimens of fresh diorite were obtained from the dump at Dunbar's mine. The rock from the main shaft is of medium fine texture and evenly crystalline. It consists of an even mixture of black hornblende and gray feldspar. Under the microscope the rock is seen to consist of greenish-brown to dark-green pleochroic hornblende and labradorite feldspar. Apatite, olivine, and magnetite occur in small amounts as accessory minerals. Specimens of diorite from a shaft about a half-mile to the south show a small amount of pale-pink orthoclase feldspar scattered through the rock.

Some of the diorite from a small intrusion which cuts the Cambrian formations a few miles north of the mine is distinctly porphyritic and consists of hornblende phenocrysts in rather slender crystals about a half-inch long in a gray ground-mass of plagioclase feldspar and hornblende. Magnetite and apatite occur in small amounts scattered through the ground-mass and are visible under the microscope. The rock is deeply weathered at the surface and the hornblende is mostly altered to chlorite, and the feldspar is kaolinized.

There are zones of altered rock along the contacts of the diorite and the Tertiary limestone which are well exposed about Dunbar's mine. In this contact zone are many secondary minerals which include garnets, and several copper-bearing minerals, chiefly chrysocolla, with some malachite and azurite. It is the presence of these minerals which has caused the development of Dunbar's mine. This mine was not in operation during the summers of 1912 and 1913 when the writer visited the region.

DIABASE

A rather large intrusion of diabase was observed by the writer in the extreme northern part of the region, about a mile west of Lombard. This somewhat irregular dikelike intrusion follows the plane of the thrust fault across the double horseshoe bend of the Missouri River and varies in width from 100 to 500 feet. The intrusion has produced a noticeable contact effect on the country rocks, particularly on the Cretaceous rocks on the east side, which are indurated near the contact.

The diabase is deeply weathered near the surface and has a rusty brown color. It forms a very conspicuous massive wall on the north side of the Missouri canyon, northwest of Lombard. The rock shows the ophitic structure well and is composed of augite and labradorite with some olivine, magnetite, and apatite. The age of this intrusion cannot be very definitely placed but it is clearly post-overthrusting, and therefore of Tertiary age.

SUMMARY

The contributions of this article may be summarized as follows:

1. A new geologic map of a portion of the Fort Logan region, and a revised geologic map of a part of the Three Forks region.

2. The recognition of an extensive overthrust in the northwestern part of the region, "the Lombard overthrust."

3. New facts relative to the stratigraphy of the region mapped, including the identification of a portion of the Belt Series, and the recognition of a disconformity between the Yogo limestone and the Jefferson limestone.

4. Detailed sections of some of the Paleozoic formations.

5. The igneous rocks and their manner of occurrence.